

# **Natural Conditions Assessment for Low pH and Low Dissolved Oxygen, Cattail Creek in Greensville County, Virginia**



**Submitted by  
Virginia Department of Environmental Quality**

**November 2011**

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## Executive Summary

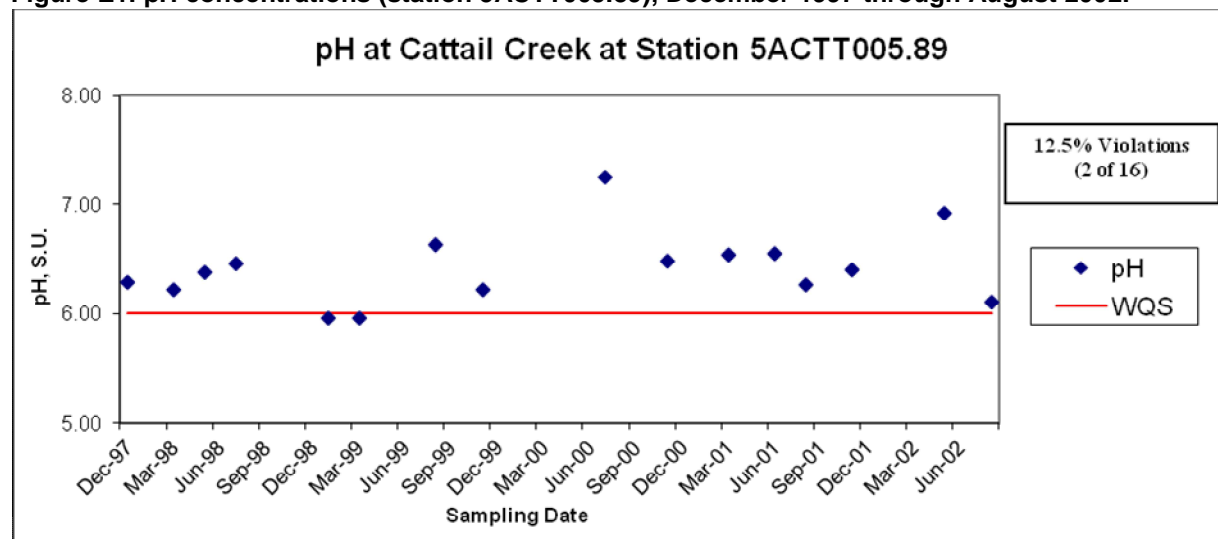
This report presents the assessment of whether low pH and dissolved oxygen (DO) in Cattail Creek are due to natural conditions or whether a Total Maximum Daily Load (TMDL) must be performed because of anthropogenic impacts. Cattail Creek is located within Greensville County, Virginia, and is a minor tributary to Fontaine Creek, a tributary of the Chowan River. The waterbody identification (WBID) and Virginia Hydrologic Unit (HUC) codes for Cattail Creek and tributaries are VAP-K11R and 03010204. Cattail Creek encompasses a total of approximately 31.79 rivermiles (National Hydrography Dataset (NHD)). Cattail Creek was listed as impaired due to violations in water quality standards for pH and dissolved oxygen. This report addresses both the pH and dissolved oxygen impairments.

The total area of the Cattail Creek watershed is approximately 15.09 square miles. The average annual rainfall is 44 inches. The watershed is approximately 9,657 acres in size and is predominately forested (56 percent). Agriculture encompasses 33 percent of the watershed, with 24 percent cropland and 9 percent pasture/hayland. Urban areas comprise approximately 3 percent of the land base. Transitional/barren areas total 1 percent of the watershed. Wetlands and open water comprise 4 percent and other grasses comprise 3 percent of the watershed.

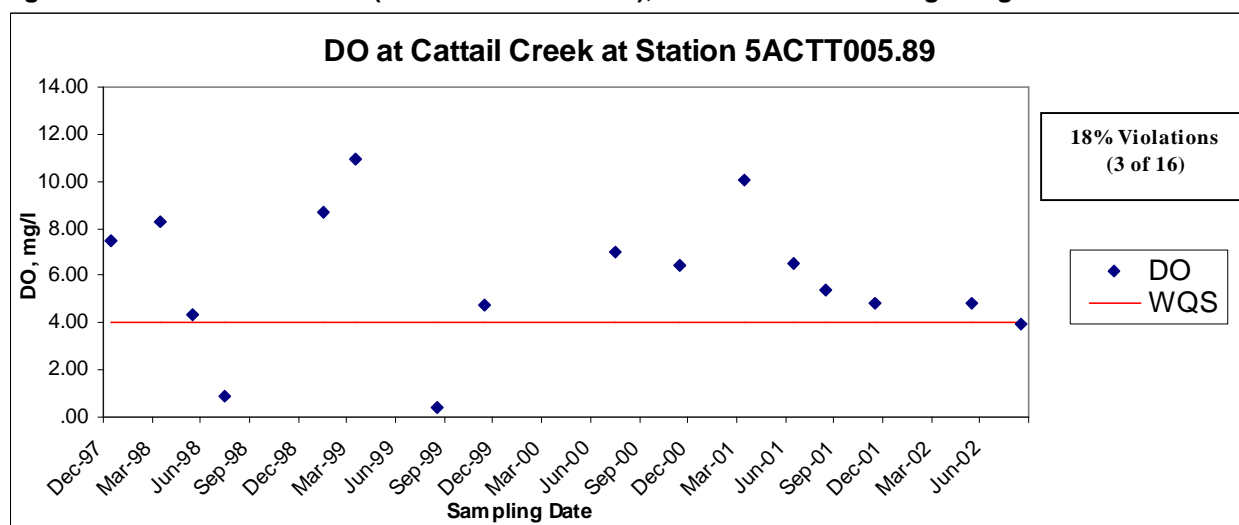
The mainstem of Cattail Creek was listed as impaired on Virginia's 2002 303(d) Total Maximum Daily Load Priority List and Report, and the 2004, 2006, and 2008 305(b) / 303(d) Integrated Reports (VADEQ, 2002, 2004, 2006, and 2008) due to violations of the State's water quality standard for pH and Dissolved Oxygen (DO). This report evaluates both the DO and pH impairments by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL.

DEQ monitored 3 stations on non-tidal Cattail Creek from December 1997 through November 2008. Of the 53 total pH data points recorded, 3 violated water quality standards for pH (5.6%), and 15 of 51 DO data points violated the water quality standards for DO concentration (29%), however 2 of 16 pH values were concentrated at one station 5ACTT005.89 (12.5%) and in the 2010 assessment 7 of 11 DO values at station 5ACTT000.46 (63%) violated the water quality standard. The original listing station for pH (5ACTT005.89) had a violation rate of 2 of 16 (12.5%), as shown in Figure E1. The DO at the original listing station had a violation rate of 3 of 16 (18%), which is shown in Figure E2.

**Figure E1. pH concentrations (station 5ACTT005.89), December 1997 through August 2002.**

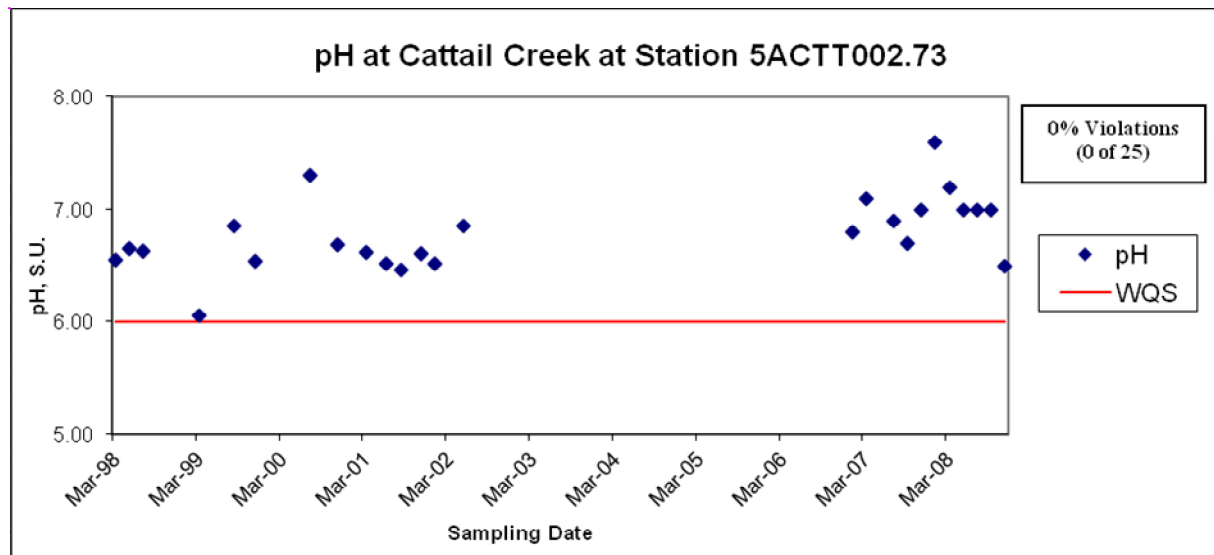


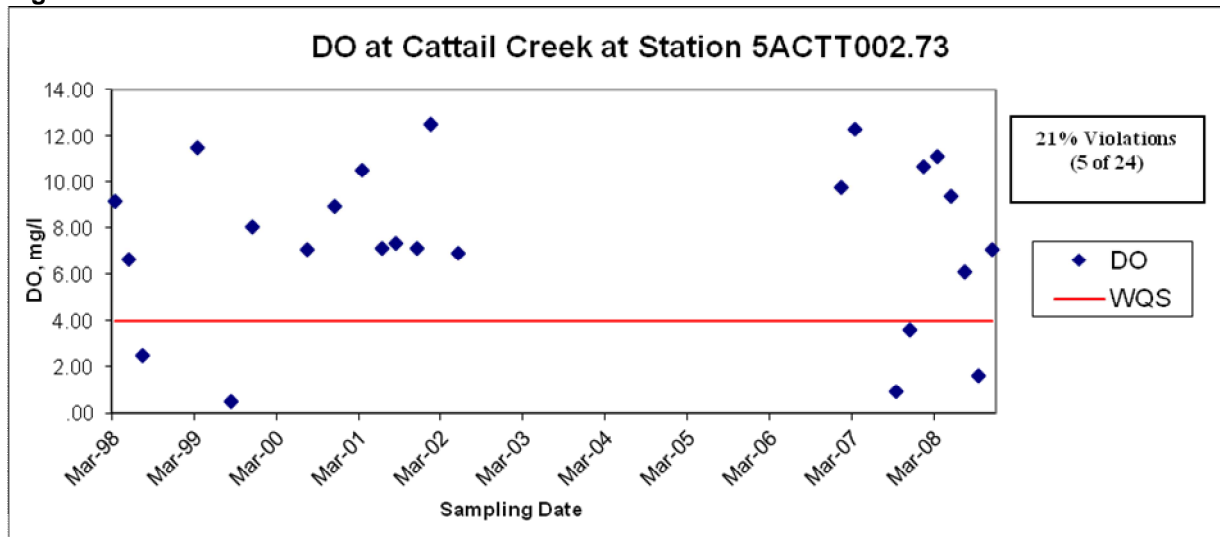
**Figure E2. DO concentrations (station 5ACTT005.89), December 1997 through August 2002.**



Time series graphs of all pH and DO data collected at the other of the two the original listing stations, Cattail Creek at station 5ACTT002.73 had a no violations of the pH standard (Figure E3), and 5 of 24 violations (21%) of the DO standard (Figure E4).

**Figure E3. pH on Cattail Creek at station 5ACTT002.73.**



**Figure E4. DO on Cattail Creek at station 5ACTT002.73.**

According to Virginia Water Quality Standards (9 VAC 25-260-10A), "all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

As indicated above, Cattail Creek must support all designated uses and meet all applicable criteria. If the waterbody violates the instantaneous DO water quality standard of 4.0 mg/l or pH values are less than 6.0 or greater than 9.0 in more than 10.5 percent of samples, the waterbody is classified as impaired and natural conditions must be determined or a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion.

In 2003 VADEQ proposed a methodology for determining whether low DO or pH originates from natural or anthropogenic sources, adapted from "Methodology for Assessing Natural Dissolved Oxygen and pH Impairments: Application to the Appomattox River Watershed, Virginia" (MapTech 2003).

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (e.g., decomposition and respiration) and oxygen restoring processes (e.g., aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. Conditions that would typically be associated with naturally low DO include slow-moving, ripple-less waters where the bacterial decay of organic matter depletes DO at a faster rate than it can be replenished. Indicators of these conditions include low slope, the presence of swamps or wetlands. These conditions often also produce low pH due to organic acids (tannins, humic and fulvic substances) produced in the decay process. These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems.

The general approach to determine if DO and pH impairments in free-flowing streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or low pH levels and for determining the likelihood of anthropogenic impacts is described below. DEQ staff use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Before implementing this procedure, all DO and pH data should be screened for flows less than the 7Q10. DO and pH data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate recalculated accordingly.

- Step 1. Determine slope and appearance (presence of wetlands).
- Step 2. Determine nutrient levels and compare with USGS background concentrations.
- Step 3. Determine degree of seasonal fluctuation (for DO only).
- Step 4. Determine anthropogenic impacts from permitted dischargers and land use.

No Cattail Creek pH or DO water quality data, standard violations or non-violations were obtained at flows below 7Q10, therefore no data were removed.

The slopes of Cattail Creek and tributaries Collier and Massie Branches were determined as 0.34%, 0.19% and 0.42%, respectively. These are lower than the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swamps and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts.

Cattail Creek and its tributaries exhibit low nutrient concentrations below national background levels in streams from undeveloped areas, which are not indicative of human impact.

Cattail Creek exhibits natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO.

There are no active permitted point source dischargers in the Cattail Creek watershed (K11R). However there is one Confined Animal Feeding Operation (CAFO) permit, Smithfield Carroll's Farm 93 (VPG100033). This facility land applies manure to fields and is designed not to discharge off the fields, therefore is not considered a point source. This facility is not expected to significantly impact DO or pH.

Urban areas compose approximately 3 percent of the land base, almost all of which occurs upstream of the impaired segment of the watershed. Agriculture makes up approximately 33 percent of the watershed. The watershed is predominately forested (56 percent), with 4 percent wetlands and open water. Land use was not considered to have significantly impacted the swampwater conditions of Cattail Creek and its tributaries. The percentages of forested and wetland landuses for tributaries Collier and Massie Branches are very similar to those on mainstem Cattail Creek.

Based on the above information, a change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is indicated for Cattail Creek located in waterbody identification code (WBID, Virginia Hydrologic Unit) K11R, a total of 31.79 rivermiles. If there is a 305(b)/303(d) assessment prior to the reclassification, Cattail Creek will be assessed as Category 4C, Impaired due to natural condition, no TMDL needed.

DEQ performed an assessment of the Cattail Creek low DO and low pH natural condition in lieu of a TMDL. Therefore neither a TMDL Technical Advisory Committee (TAC) meeting nor a public meeting was involved. Public participation will occur during the next water quality standards triennial review process.

## **1. Introduction**

Cattail Creek is located within Greensville County, Virginia, and is a minor tributary of Fontaine Creek, a tributary of the Chowan River. There are 31.79 total stream miles in the Cattail Creek watershed (National Hydrography Dataset (NHD) using GIS. The impaired segment for low pH is 5.33 miles in length and for DO is 7.38 miles in length, both on the mainstem of Cattail Creek. Cattail Creek generally flows east from the headwaters southwest of Brink, VA, to the confluence with Fontaine Creek just after it intersects Interstate 95. The watershed totals approximately 15.09 mi<sup>2</sup>. There is no continuous flow gauging station on Cattail Creek.

## **2. Physical Settings**

### **2.1. *Listed Water Bodies***

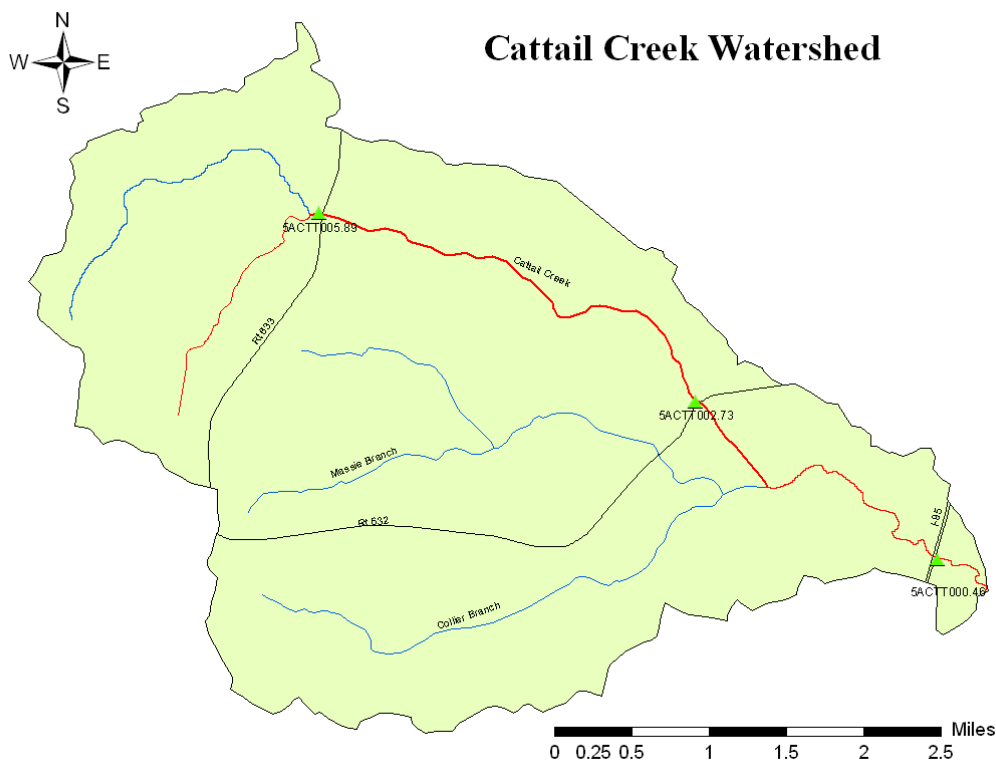
The mainstem of Cattail Creek was listed as impaired on Virginia's 2002 303(d) Total Maximum Daily Load Priority List and Report, and the 2004, 2006, 2008, and 2010 305(b) / 303(d) Integrated Reports (VADEQ, 2002, 2004, 2006, 2008, and 2010) due to violations of the State's water quality standard for pH and DO. This report evaluates both the DO and pH impairments by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL. The waterbody identification code (WBID, Virginia Hydrologic Unit) for non-tidal Cattail Creek is VAP-K11R.

### **2.2. *Watershed***

#### **2.2.1. General Description**

Cattail Creek flows east from the headwaters southwest of Brink, VA, to the confluence with Fontaine Creek just after it intersects interstate 95. The total area of the watershed is approximately 15.09 square miles. See Figure 1 for a map of the watershed including monitoring stations.

**Figure 1. The Cattail Creek watershed map and associated monitoring stations.**



## 2.2.2. Geology, Climate, Land Use

### ***Geology and Soils***

The impaired segment of the Cattail Creek is predominately within the Atlantic Coastal Plain physiographic region, though the headwaters of some tributaries are located within the lower Piedmont physiographic province. The Atlantic Coastal Plain is the easternmost of Virginia's physiographic provinces. The Atlantic Coastal Plain extends from New Jersey to Florida, and includes all of Virginia east of the Fall Line. The Fall Line is the easternmost extent of rocky river rapids, the point at which east-flowing rivers cross from the hard, igneous and metamorphic rocks of the Piedmont to the relatively soft, unconsolidated strata of the Coastal Plain. The Coastal Plain is underlain by layers of Cretaceous and younger clay, sand, and gravel that dip gently eastward. These layers were deposited by rivers carrying sediment from the eroding Appalachian Mountains to the west. As the sea level rose and fell, fossiliferous marine deposits were interlayered with fluvial, estuarine, and beach strata. The youngest deposits of the Coastal Plain are sand, silt and mud presently being deposited in our bays and along our beaches ([http://www.dcr.virginia.gov/natural\\_heritage/documents/overviewPhysiography\\_vegetation.pdf](http://www.dcr.virginia.gov/natural_heritage/documents/overviewPhysiography_vegetation.pdf)).

Soils for the Cattail Creek watershed were documented utilizing the VA State Soil Geographic Database (STATSGO). Three general soil types were identified using in this database. Descriptions of these soil series were derived from queries to the USDA Natural Resources Conservation Service (NRCS) Official Soil Series Description web site (<http://soils.usda.gov/technical/classification/osd/index.html>). Figure 2 shows the location of these general soil types in the watershed.

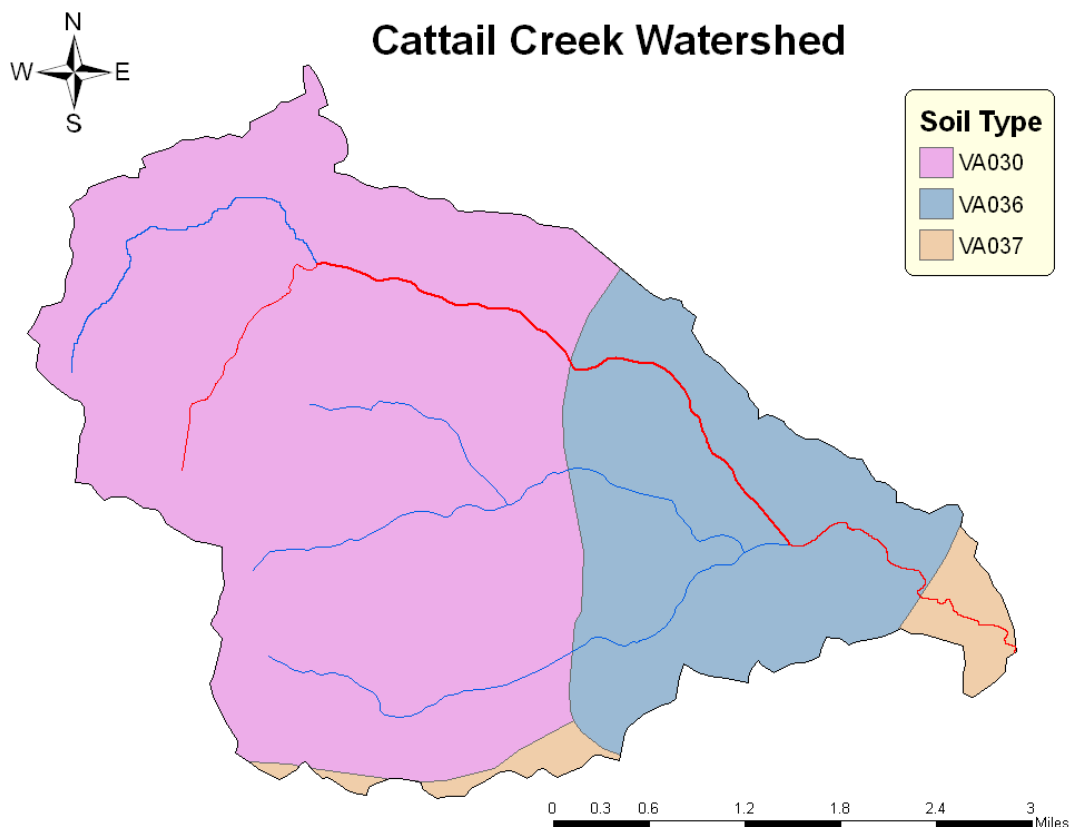
Soils of the **Appling-Wedowee-Ashlar-Louisburg-Vance-Worsham series (VA030)** moderate to very deep that formed in residuum from weathered igneous, metamorphic, and crystalline rock of the Piedmont Plateau. Soils range from excessively to poorly drained, with moderately rapid to slow permeability.

Soils of the **Tetotum-Nansemond-State-Emporia-Dragston-Nimmo-Bladen (VA036)** series are very deep and range from well drained to poorly drained. Permeability ranges from moderately rapid and/or

rapid to moderately slow or slow. This soil series was formed in sandy or loamy fluvial and marine sediments on Coastal Plain uplands and stream terraces.

Soils of the **Bibb and Levy-Bohicket-Lumbee-Nansemond-Rumford-Tetotum-State-Suffolk (VA037)** Series are very deep to deep, and vary from well drained to very poorly drained. They range in slope from 0 – 15 percent. Their water capacity varies from low to high. This soils series was formed in sandy to loamy to mucky clay alluvial and marine sediments on the upper Coastal Plain and stream terraces.

**Figure 2. Soil Characteristics of the Cattail Creek Watershed.**



### ***Climate***

The climate summary for the Cattail Creek comes from a weather station located in Emporia, VA (442790) with a period of record from 1893 to 2010. The average annual maximum and minimum temperatures (°F) at the weather station are 70.4 and 46.7 and the annual rainfall (inches) is 43.97 (Table 1) (Southeast Regional Climate Center, [http://www.sercc.com/climateinfo/historical/historical\\_va.html](http://www.sercc.com/climateinfo/historical/historical_va.html)).

**Table 1. Climate summary for Emporia, Virginia (442790).**

|                                     | Jan  | Feb  | Mar  | Apr  | May  | Jun  | Jul  | Aug  | Sep  | Oct  | Nov  | Dec  | Annual |
|-------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|--------|
| <b>Average Max. Temperature (F)</b> | 49.4 | 52.9 | 60.9 | 70.6 | 78.0 | 85.8 | 89.3 | 87.9 | 81.8 | 71.9 | 62.8 | 53.0 | 70.4   |

|  |      |      |      |      |      |      |      |      |      |      |      |      |       |
|--|------|------|------|------|------|------|------|------|------|------|------|------|-------|
| <b>Average Min. Temperature (F)</b>      | 27.2 | 29.3 | 35.8 | 44.6 | 53.8 | 63.0 | 67.8 | 65.8 | 58.9 | 46.8 | 37.6 | 30.2 | 46.7  |
| <b>Average Total Precipitation (in.)</b> | 3.35 | 3.07 | 3.77 | 3.30 | 3.88 | 3.73 | 5.24 | 4.55 | 4.05 | 2.92 | 2.91 | 3.22 | 43.98 |

### **Land Use**

The Cattail Creek watershed extends from approximately 1 mile south of Brink to approximately 1 mile north of Turners Crossroads. It is approximately 5 - 6 miles long and 3 miles wide. The watershed is approximately 9657 acres (15.09 mi<sup>2</sup>) in size and is predominately forested (56 percent). Agriculture comprises 33 percent of the watershed, with 24 percent cropland and 9 percent pasture/hayland. Urban areas compose approximately 3 percent of the land base. The remaining 8 percent of the watershed is comprised of 1 percent barren areas, 4 percent wetlands and open water, and 3 percent other grasses. Land use is described in Table 2.

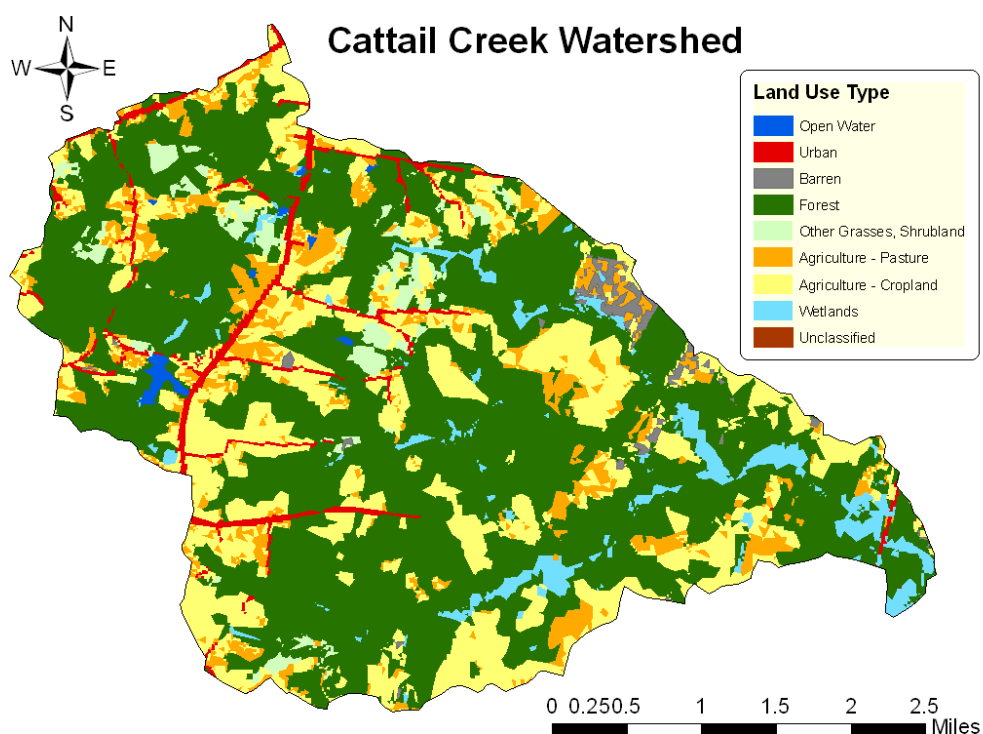
A map of the distribution of land use in the watershed (Figure 3) shows that urban land use is concentrated around route 633 near the headwaters and around interstate 95 near the mouth, and wetlands / water land use is concentrated along the mainstem in the center and downstream portions to the mouth.

It is evident from Figure 3 that the percentages of forested and wetland landuses for tributaries Collier and Massie Branches are very similar to those on mainstem Cattail Creek.

**Table 2. Land Use in the Cattail Creek and Tributaries Watershed**

| <b>Land Use Type</b> | <b>Acres</b>   | <b>Square Miles</b> | <b>Percent</b> |
|----------------------|----------------|---------------------|----------------|
| Open Water           | 37.97          | 0.06                | 0%             |
| Urban                | 271.32         | 0.42                | 3%             |
| Barren or Mining     | 98.98          | 0.15                | 1%             |
| Transitional         | 0.00           | 0.00                | 0%             |
| Forest               | 5386.95        | 8.42                | 56%            |
| Agri - Pasture       | 841.89         | 1.32                | 9%             |
| Agri - Cropland      | 2324.43        | 3.63                | 24%            |
| Other Grasses        | 298.21         | 0.47                | 3%             |
| Wetland              | 397.33         | 0.62                | 4%             |
| <b>Totals:</b>       | <b>9657.08</b> | <b>15.09</b>        | <b>100%</b>    |

**Figure 3. Land Use in the Cattail Creek Watershed**



### 3. Description of Water Quality Problem/Impairment

The mainstem of Cattail Creek was listed as impaired on Virginia's 2002 303(d) Total Maximum Daily Load Priority List and Report, and the 2004, 2006, 2008, and 2010 305(b) / 303(d) Integrated Reports (VADEQ, 2002, 2004, 2006, 2008, and 2010) due to violations of the State's water quality standard for pH and Dissolved Oxygen. This report evaluates both the pH and DO impairments by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL.

DEQ monitored 3 stations on non-tidal Cattail Creek (Figure 1) with dates ranging from December 1997 through November 2008. Of the 53 total pH data points recorded, 3 violated water quality standards for pH (5.6%), and 15 of 51 DO data points violated the water quality standards for DO concentration (29%), however 2 of 16 pH values were concentrated at one station 5ACTT005.89 (12.5%) and in the 2010 assessment 7 of 11 DO values at station 5ACTT000.46 (63%) violated the water quality standard. The pH minimum and maximum values ranged from 5.90 to 7.60 S. U., and DO values ranged from 0.40 to 12.51 mg/l. The results are summarized in Table 3.

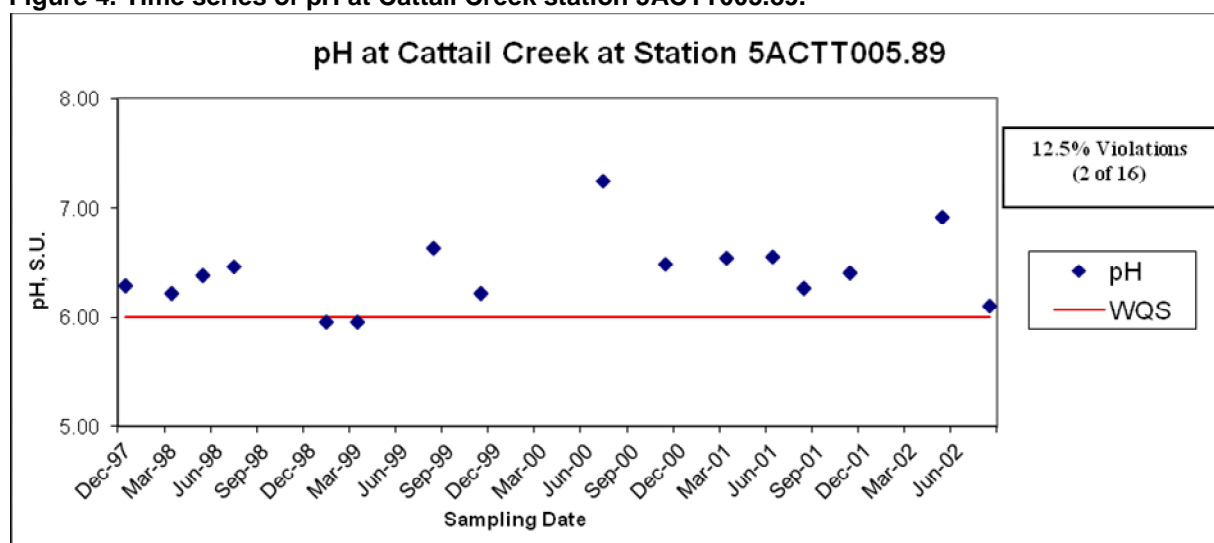
**Table 3. pH and DO data collected by DEQ from 3 stations on Cattail Creek.**

|             |                         | Number of Samples |    | SU         |            | mg/l       |            | Number of Violations |    |
|-------------|-------------------------|-------------------|----|------------|------------|------------|------------|----------------------|----|
| Station     | Sample Period           | pH                | DO | Average pH | Min-Max pH | Average DO | Min-Max DO | pH                   | DO |
| 5ACTT000.46 | 1/29/2007 to 12/10/2007 | 12                | 11 | 6.38       | 5.90-7.00  | 4.75       | .20-11.70  | 1                    | 7  |
| 5ACTT002.73 | 3/30/1998 to 11/17/2008 | 25                | 24 | 6.79       | 6.05-7.60  | 7.44       | .49-12.51  | 0                    | 5  |

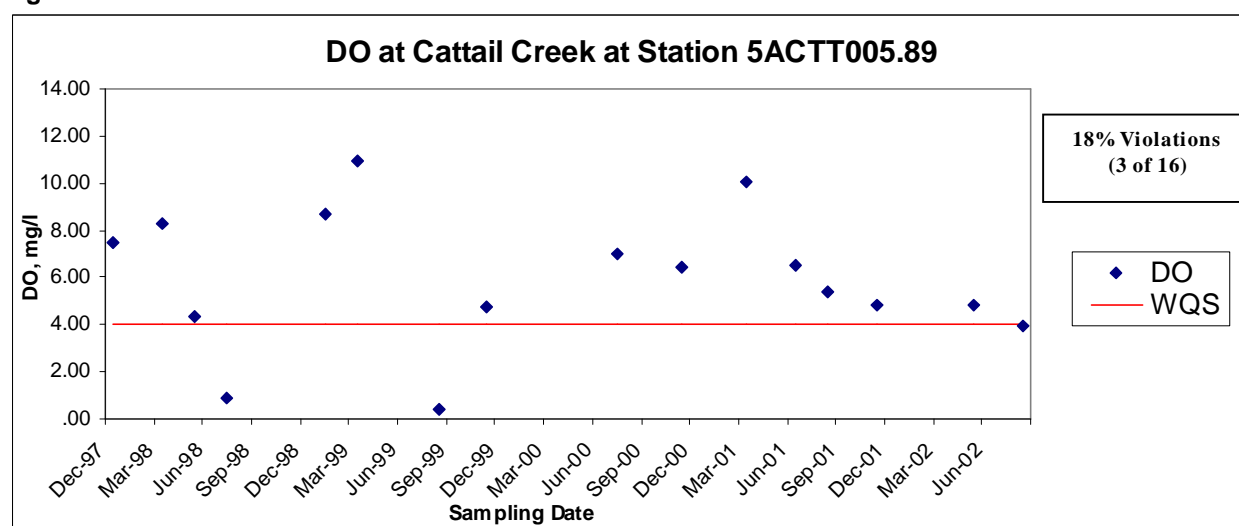
|             |                            |    |    |      |           |      |           |   |   |
|-------------|----------------------------|----|----|------|-----------|------|-----------|---|---|
| 5ACTT005.89 | 12/22/1997<br>to 8/29/2002 | 16 | 16 | 6.41 | 5.96-7.25 | 5.92 | .40-10.97 | 2 | 3 |
|-------------|----------------------------|----|----|------|-----------|------|-----------|---|---|

Time series graphs of all pH and DO data collected at one of the two the original listing stations, Cattail Creek at station 5ACTT005.89, shows the pH ranging from 5.96 to 7.25 (Figure 4) and DO ranged from .40 mg/l to 10.97 mg/l (Figure 5). The horizontal red line at the pH = 6.0 mark represents the minimum water quality standard. The data points below the pH = 6.0 line are violations of the water quality standard in Figure 4. The horizontal red line at the DO = 4.0 mark represents the minimum water quality standard in Figure 5. The data points below the DO = 4.0 line are violations of the water quality standard in Figure 5.

**Figure 4. Time series of pH at Cattail Creek station 5ACTT005.89.**

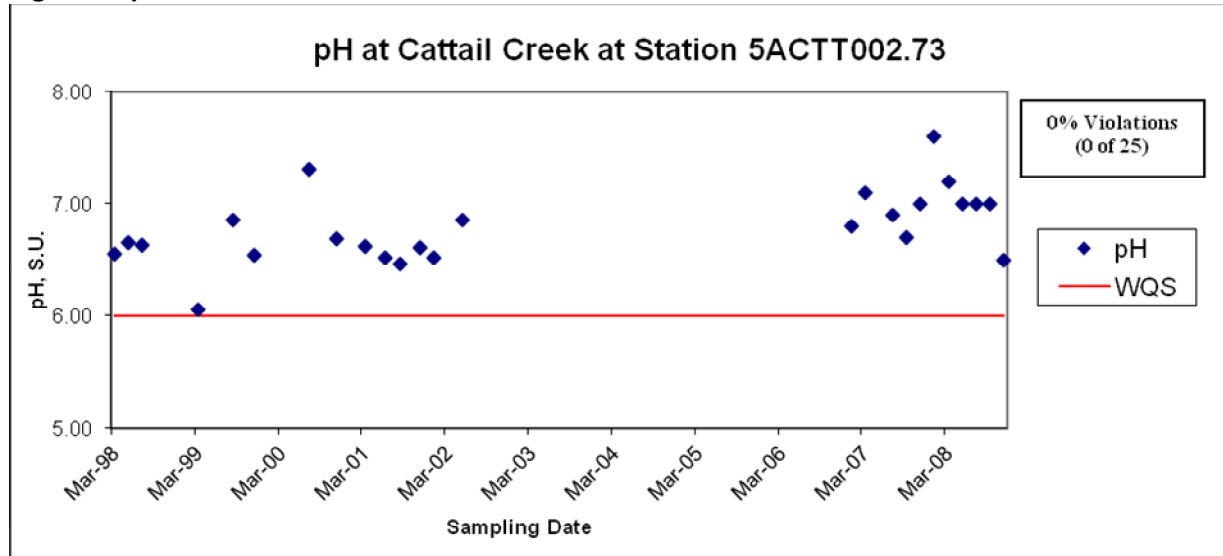


**Figure 5. Time series of DO at Cattail Creek station 5ACTT005.89.**

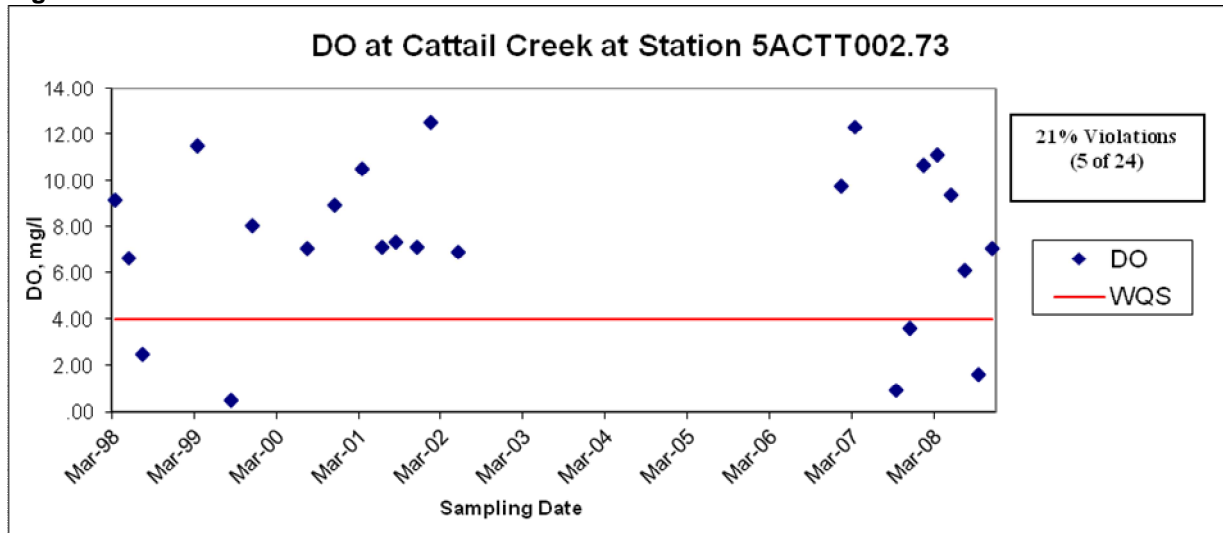


Time series graphs of all pH and DO data collected at the other of the two the original listing stations, Cattail Creek at station 5ACTT002.73, shows the pH ranging from 6.05 to 7.60 (Figure 6) and DO ranged from 0.49 mg/l to 12.51 mg/l (Figure 7). The horizontal red line at the pH = 6.0 mark represents the minimum water quality standard in Figure 6. The data points below the pH = 6.0 line illustrate violations of the water quality standard in Figure 6. The horizontal red line at the DO = 4.0 mark represents the minimum water quality standard in Figure 7. The data points below the DO = 4.0 line are violations of the water quality standard in Figure 7.

**Figure 6. pH on Cattail Creek at station 5ACTT002.73.**



**Figure 7. DO on Cattail Creek at station 5ACTT002.73.**



### 3.1 Associated pH and DO of Cattail Creek

DEQ also monitored and collected pH and DO data at one other station on Cattail Creek for the assessment of low pH and DO due to the natural conditions. Associated stations with pH and DO data are presented in Figures 8 and 9 below.

Figure 8. pH on Cattail Creek at station 5ACTT000.46.

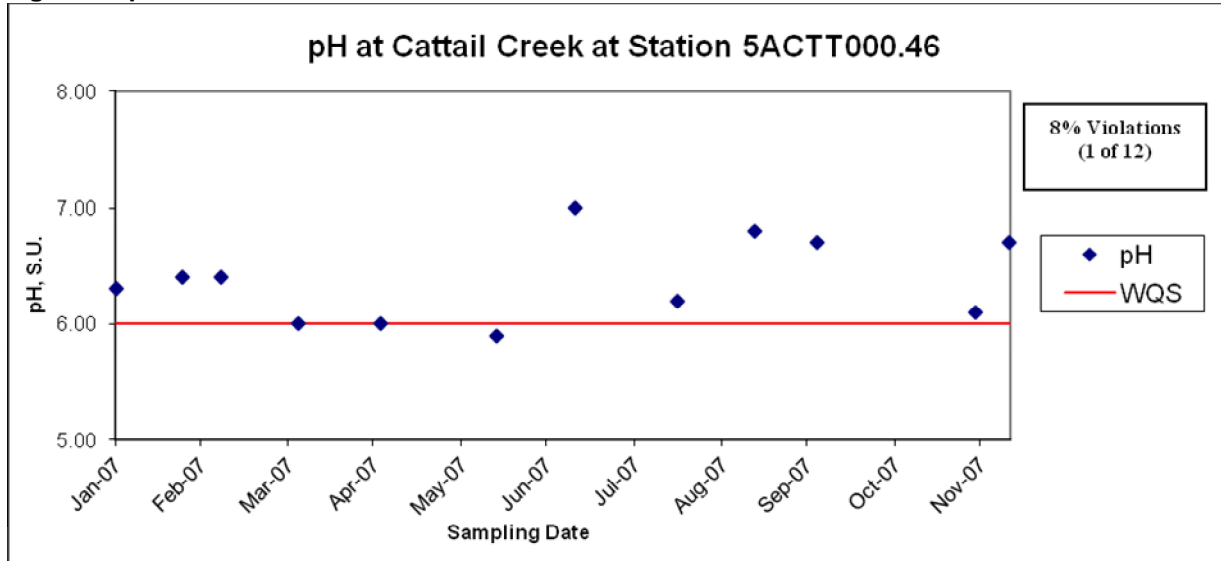
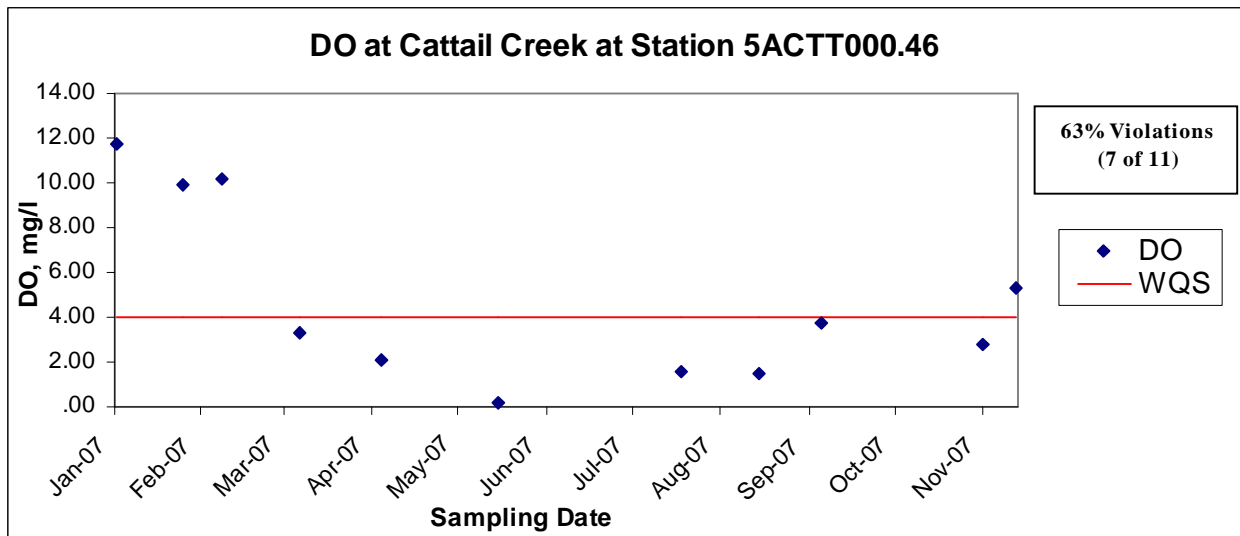


Figure 9. DO on Cattail Creek at station 5ACTT000.46.



All stations monitored on Cattail Creek exceeded the water quality standards for DO in more than 10 percent of visits. Only Cattail Creek station 5ACTT005.89 in the upstream mainstem exceeded the pH standard in more than 10 percent of visits.

#### 4. Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term “water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.).”

As stated above, Virginia water quality standards consist of a designated use or uses and water quality criteria. These two parts of the applicable water quality standard are presented in the sections that follow.

#### 4.1. Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10A), “all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish).”

As stated above, Cattail Creek must support all designated uses and meet all applicable criteria.

#### 4.2. Applicable Water Quality Criteria

The applicable water quality criteria for DO and pH in the Cattail Creek watershed are an instantaneous minimum DO of 4.0 mg/l and pH from 6.0 SU to 9.0 SU, as in Table 4.

| <b>Table 4. Applicable water quality standards</b> |                      |                      |
|--|----------------------|----------------------|
| <b>Parameter</b>                                   | <b>Minimum, mg/l</b> | <b>Maximum, mg/l</b> |
| <i>pH</i>  | 6.0                  | 9.0                  |
| <i>DO</i>  | 4.0                  | -                    |

If the waterbody exceeds the criterion listed above in more than 10.5 percent of samples, the waterbody is classified as impaired and natural conditions must be determined or a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion.

### 5. Assessment of Natural Conditions Affecting low DO - Process for determining if DO and pH impairments in free-flowing streams are due to natural conditions.

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (e.g., decomposition and respiration) and oxygen-restoring processes (e.g., aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. The level of pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity. Conditions in a stream that would typically be associated with naturally low DO and pH include slow-moving, ripple-less waters or wetlands where the decay of organic matter produces organic acids. These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems. The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below.

- Step 1. Determine slope and appearance.
- Step 2. Determine nutrient levels.
- Step 3. Determine degree of seasonal fluctuation (for DO only).
- Step 4. Determine anthropogenic impacts.

**The results from this methodology (or process or approach) will be used to determine if the stream should be re-classified as Class VII Swamp Waters. Each step is described in detail below.**

# Procedure for Natural Condition Assessment of low pH and low DO in Virginia Streams

Prepared by Virginia Department of Environmental Quality  
October 2004

## I. INTRODUCTION

Virginia's list of impaired waters currently shows many waters as not supporting the aquatic life use due to exceedances of pH and/or DO criteria that are designed to protect aquatic life in Class III waters. However, there is reason to believe that most of these streams or stream segments have been mis-classified and should more appropriately be classified as Class VII, Swamp Waters. This document presents a procedure for assessing if natural conditions are the cause of the low pH and/or low DO levels in a given stream or stream segment.

The level of dissolved oxygen (DO) in a water body is determined by a balance between oxygen-depleting processes (e.g., decomposition and respiration) and oxygen-restoring processes (e.g., aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. The level of acidity as registered by pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity.

Conditions in a stream that would typically be associated with naturally low DO and/or naturally low pH include slow-moving, ripple-less waters. In such waters, the decay of organic matter depletes DO at a faster rate than it can be replenished and produces organic acids (tannins, humic and fulvic substances). These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems.

The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural

conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below. DEQ staff is proposing to use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Waters that are shown to have naturally low DO and pH levels will be re-classified as Class VII, Swamp Waters, with the associated pH criterion of 4.3 to 9.0 SU. An associated DO criterion is currently being developed from swamp water data. A TMDL is not needed for these waters. An assessment category of 4C will be assigned until the waterbody has been re-classified.

## **II. NATURAL CONDITION ASSESSMENT**

Following a description of the watershed (including geology, soils, climate, and land use), a description of the DO and/or pH water quality problem (including a data summary, time series and monthly data distributions), and a description of the water quality criteria that were the basis for the impairment determination, the available information should be evaluated in four steps.

### **Step 1. Determine appearance and flow/slope.**

Streams or stream segments that have naturally low DO (< 4 mg/L) and low pH (< 6 SU) are characterized by very low slopes and low velocity flows (flat water with low reaeration rates). Decaying vegetation in such swampy waters provides large inputs of plant material that consumes oxygen as it decays. The decaying vegetation in swamp water also produces acids and decreases pH. Plant materials contain polyphenols such as tannin and lignin. Polyphenols and partially degraded polyphenols build up in the form of tannic acids, humic acids, and fulvic acids that are highly colored. The trees of swamps have higher polyphenolic content than the soft-stemmed vegetation of marshes. Swamp streams (blackwater) are therefore more highly colored and more acidic than marsh streams.

Appearance and flow velocity (or slope if flow velocity is not available) must be identified for each stream or stream segment to be assessed for natural conditions and potential re-classification as Class VII swamp water. This can be done through maps, photos, field measurements or other appropriate means.

### **Step 2. Determine nutrient levels.**

Excessive nutrients can cause a decrease in DO in relatively slow moving systems, where aeration is low. High nutrient levels are an indication of anthropogenic inputs of nitrogen, phosphorus, and possibly organic matter. Nutrient input can stimulate plant growth, and the resulting die-off and decay of excessive plankton or macrophytes can decrease DO levels.

USGS (1999) estimated national background nutrient concentrations in streams and groundwater from undeveloped areas. Average nitrate background concentrations are less than 0.6 mg/L for streams, average total nitrogen (TN) background concentrations are less

than 1.0 mg/L, and average background concentrations of total phosphorus (TP) are less than 0.1 mg/L.

Nutrient levels must be documented for each stream or stream segment to be assessed for natural conditions and potential re-classification as Class VII swamp water. Streams with average concentrations of nutrients greater than the national background concentrations should be further evaluated for potential impacts from anthropogenic sources.

Step 3. Determine degree of seasonal fluctuation (for DO only).

Anthropogenic impacts on DO will likely disrupt the typical seasonal fluctuation seen in the DO concentrations of wetland streams. Seasonal analyses should be conducted for each potential Class VII stream or stream segment to verify that DO is depressed in the summer months and recovers during the winter, as would be expected in natural systems. A weak seasonal pattern could indicate that human inputs from point or nonpoint sources are impacting the seasonal cycle.

Step 4. Determine anthropogenic impacts.

Every effort should be made to identify human impacts that could exacerbate the naturally low DO and/or pH. For example, point sources should be identified and DMR data analyzed to determine if there is any impact on the stream DO or pH concentrations. Land use analysis can also be a valuable tool for identifying potential human impacts.

Lastly, a discussion of acid rain impacts should be included for low pH waters. The format of this discussion can be based either on the process used for the recent Class VII classification of several streams in the Blackwater watershed of the Chowan Basin (letter from DEQ to EPA, 14 October 2003). An alternative is a prototype regional stream comparison developed for Fourmile Creek, White Oak Swamp, Matadequin Creek and Mechumps Creek (all east of the fall line). The example analysis under IV in this document, or the example report prepared for Fourmile Creek, illustrate this approach. For streams west of the fall line, a regional stream comparison for 2004 analyses encompasses Winticomack, Winterpock, and Chickahominy Rivers.

7Q10 Data Screen

If the data warrant it, a data screen should be performed to ensure that the impairment was identified based on valid data. All DO or pH data that violate water quality standards should be screened for flows less than the 7Q10. Data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate recalculated accordingly. Only those waters with violation rates determined days with flows > or = 7Q10 flows should be classified as impaired.

In some cases, data were collected when flow was 0 cfs. If the 7Q10 is identified as 0 cfs as well, all data collected under 0 cfs flow would need to be considered in the water quality assessment. In those cases, the impairment should be classified as 4C, impaired due to natural conditions, no TMDL needed. However, a reclassification to Class VII may not always be appropriate.

### III. NATURAL CONDITION CONCLUSION MATRIX

The following decision process should be applied for determining whether low pH and/or low DO values are due to natural conditions and justify a reclassification of a stream or stream segment as Class VII, Swamp Water.

If velocity is low or if slope is low (<0.50%) AND  
If wetlands are present along stream reach AND  
If no point sources or only point sources with minimal impact on DO and pH AND  
If nutrients are < typical background  
❖ average (= assessment period mean) nitrate less than 0.6 mg/L  
❖ average total nitrogen (TN) less than 1.0 mg/L, and  
❖ average total phosphorus (TP) are less than 0.1 mg/L AND  
For DO: If seasonal fluctuation is normal AND  
For pH: If nearby streams without wetlands meet pH criteria OR if no correlation between in-stream pH and rain pH,

THEN determine as impaired due to natural condition  
→ assess as category 4C in next assessment  
→ initiate WQS reclassification to Class VII Swamp Water  
→ get credit under consent decree

The analysis must state the extent of the natural condition based on the criteria outlined above. A map showing land use, point sources, water quality stations and, if necessary, the delineated segment to be classified as swamp water should be included.

In cases where not all of these criteria apply, a case by case argument must be made based on the specific conditions in the watershed.

#### **5.1 Preliminary Data Screen for Low Flow 7Q10**

The 7Q10 flow of a stream is the lowest streamflow for seven consecutive days that occurs on average once every ten years. The first step for low flow 7Q10 screening is to determine the most accurate 7Q10 available. The 7Q10 flow for the Cattail Creek and tributaries may be estimated by a drainage area ratio of the Cattail Creek watershed (15.09 mi<sup>2</sup>) with the 7Q10 flow at the long-term continuous gauging station Stony Creek near Dinwiddie, VA, (USGS:02046000), with a drainage area of 112 mi<sup>2</sup> and a 7Q10 of 0.31 cfs. Thus the 7Q10 of Cattail Creek is estimated at 0.042 cfs.

The DO Instantaneous Water Quality Standard applies **AT** 7Q10 flow, but **NOT** below 7Q10 flow (9 VAC 25-260-50 \*\*\*). Therefore in streams where the 7Q10 > 0.0 cfs, DO less than 4.0 mg/l taken at flows below 7Q10 are not water quality standard violations. However, in streams where the 7Q10 = 0.0 cfs, **ALL** DO data < 4.0 mg/l are standard violations, even if the flow = 0 cfs when the DO was taken.

No Cattail Creek and tributaries pH or DO water quality data, standard violations or non-violations were obtained at flows below 7Q10, therefore no data were removed.

#### **5.2 Low slope, Swamps, Wetlands or Large Forested Areas**

The slopes of Cattail Creek and tributaries Collier and Massie Branches were determined as 0.34%, 0.19% and 0.42%, respectively (Table 5). These are lower than the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swamps and heavy

tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts.

**Table 5. Calculated percent slopes for Cattail Creek.**

| Stream         | % Slope | Upstream Elevation (Feet) at<br>Rivermile (RM) | Downstream Elevation (Feet)<br>at Rivermile (RM) |
|----------------|---------|--|--|
| Cattail Creek  | 0.34    | 190' at RM 7.12                                | 80' at RM 0.96                                   |
| Collier Branch | 0.19    | 110' at RM 2.12                                | 90' at RM 0.13                                   |
| Massie Branch  | 0.42    | 130' at RM 1.62                                | 90' at RM -0.19, DS on<br>Collier Branch         |

Visual inspections of Cattail Creek and tributaries revealed swampy areas with heavy tree canopy. Decomposition of vegetative matter from large swampy areas lowers DO and pH as decay occurs. (Figures 10-13).

**Figure 10. Cattail Creek, Rt. 629, Upstream, above 5 ft. beaverdam.**



**Figure 11. Cattail Creek at Frontage Rd. F-128, Downstream, with swampy side channels..**



**Figure 12. Cattail Creek, Rt. 633, Upstream, at UT confluence, old beaverdam with swamp upstream.**



**Figure 13. Massie Branch, Rt. 632, Downstream right, swampy inflow.**

### 5.3 Instream Nutrients

The VADEQ collected nutrient data from the original listing station 5ACTT005.89, and at station 5ACTT002.73 (December 1997 to November 2008, Tables 6 and 7). The average nutrient concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of nitrate < 0.6 mg/l; TN (TKN + NO<sub>3</sub> + NO<sub>2</sub>) < 1.0 mg/l; and TP < 0.1 mg/l. These low nutrient levels are not indicative of human impact. The samples from 8/29/2002 were removed from the dataset due to extremely high concentrations from a prolonged very low and zero flow event lasting 20 days prior to the sample date, during which nutrient levels became concentrated. These elevated concentrations were then flushed downstream by a small rainfall event peaking at an estimated 1.3 cfs on the sample date. These excessive nutrient concentrations from low and zero flow days were sufficient to skew the average nutrient results above the USGS national backgrounds for undeveloped streams. Nutrient data from this sample date were considered outliers and were not included in the averages below.

**Table 6. Instream Nutrients of Cattail Creek 5ACTT005.89**

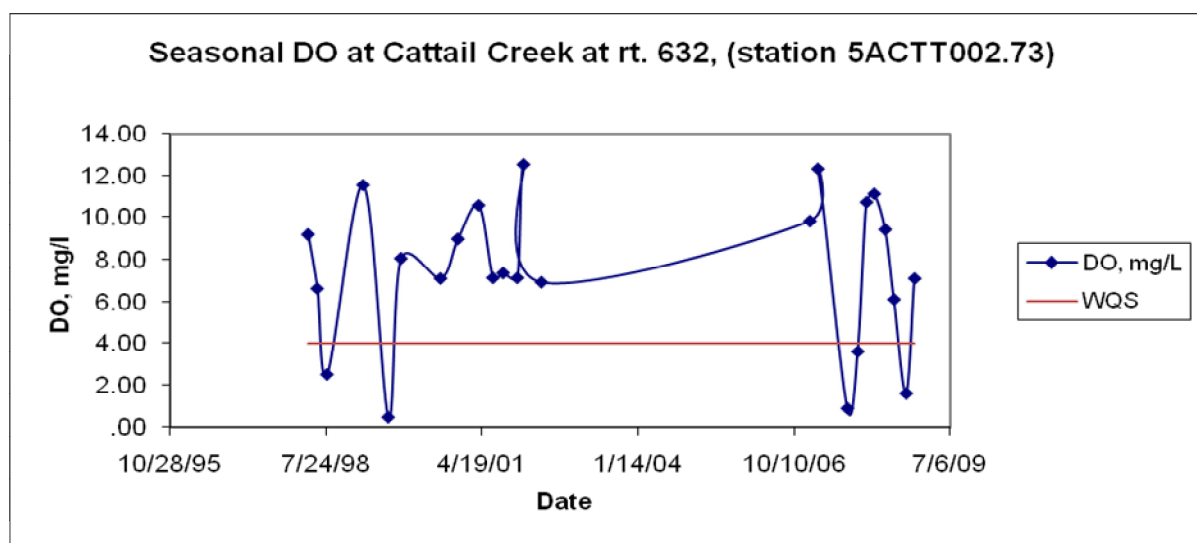
| Parameter   | Average Conc.     | Number |
|---|-------------------|--------|
| <b>Total Phosphorus</b>                           | <b>0.062 mg/l</b> | (n=18) |
| Orthophosphorus                                   | 0.029 mg/l        | (n=19) |
| Total Kjeldahl Nitrogen                           | 0.700 mg/l        | (n=18) |
| Ammonia as N                                      | 0.089 mg/l        | (n=19) |
| <b>Nitrate as N</b>                               | <b>0.105 mg/l</b> | (n=19) |
| Nitrite as N                                      | 0.011 mg/l        | (n=19) |
| <b>TN (TKN + NO<sub>3</sub> + NO<sub>2</sub>)</b> | <b>0.812 mg/l</b> | (n=18) |
| Nitrite + Nitrate, Total as N                     | 0.111 mg/l        | (n=18) |

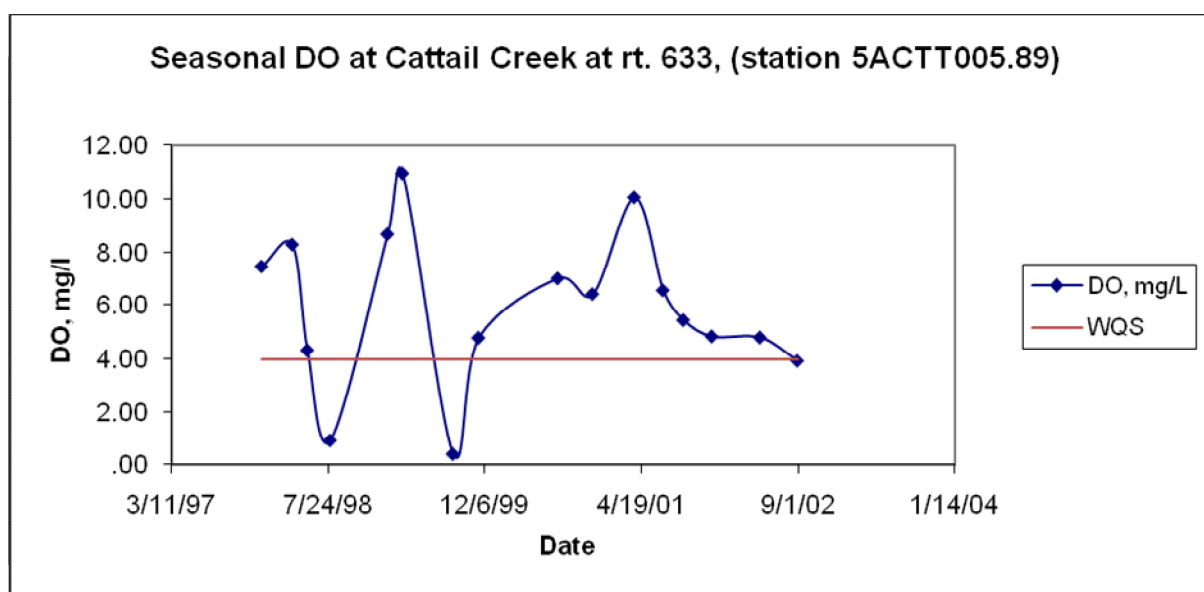
**Table 7. Instream Nutrients of Cattail Creek 5ACTT002.73**

| Parameter   | Average Conc.     | Number |
|---|-------------------|--------|
| <b>Total Phosphorus</b>                           | <b>0.092 mg/l</b> | (n=30) |
| Orthophosphorus                                   | 0.064 mg/l        | (n=18) |
| Total Kjeldahl Nitrogen                           | 0.672 mg/l        | (n=18) |
| Ammonia as N                                      | 0.089 mg/l        | (n=25) |
| <b>Nitrate as N</b>                               | <b>0.204 mg/l</b> | (n=18) |
| Nitrite as N                                      | 0.012 mg/l        | (n=18) |
| <b>TN (TKN + NO<sub>3</sub> + NO<sub>2</sub>)</b> | <b>0.860 mg/l</b> | (n=30) |
| Nitrite + Nitrate, Total as N                     | 0.223 mg/l        | (n=25) |

### 5.4 Natural Seasonal DO Fluctuation

The historical data collected at the Cattail Creek original listing station 5ACTT005.89 and at station 5ACTT002.73 were graphed to demonstrate the natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO. DO is high in the winter months while water temperatures are low, and low in the summer months when water temperatures are high. This is depicted in Figures 14 and 15.

**Figure 14. Seasonal DO Variation at Cattail Creek at Rt. 632, March 1998 through November 2008.****Figure 15. Seasonal DO Variation at Cattail Creek at Rt. 633, December 1997 through August 2002.**



### 5.5 Impact from Point Source Dischargers and Land Use

There are no active permitted point source dischargers in the Cattail Creek watershed (K11R). However there is one Confined Animal Feeding Operation (CAFO) permit, Smithfield Carroll's Farm 93(VPG100033). This facility land applies manure to fields and is designed not to discharge off the fields, therefore is not considered a point source. The maximum number of swine allowed at the facility is 5100 with an average weight of 150 lbs. This facility is not expected to significantly impact DO or pH.

**Table 8. Permitted dischargers located within the Cattail Creek.**

| Facility                     | Permit    | Design Flow (MGD) | pH  | DO (mg/L) | CBOD5 (mg/L) | TKN (mg/L) | Receiving Stream |
|------------------------------|-----------|-------------------|-----|-----------|--------------|------------|------------------|
| Smithfield Carroll's Farm 93 | VPG100033 | N/A               | N/A | N/A       | N/A          | N/A        | Cattail Creek    |

Urban areas compose approximately 3 percent of the land base, almost all of which occurs along 4 miles of Rts. 633 and 632, upstream of most of the impaired segment of the watershed. Agriculture makes up approximately 33 percent of the watershed. The watershed is predominately forested (56 percent), with 4 percent wetlands and open water. Land use was not considered to have significantly impacted the swampwater conditions of Cattail Creek and its tributaries.

## 6. CONCLUSION

**The following decision process is proposed for determining whether low DO values are due to natural conditions:**

If slope is low (<0.50) AND

If wetlands or large areas of forested land are present along stream reach AND

If no point sources or point sources with minimal impact on DO AND

If nutrients are < typical background

- ❖ average (= assessment period mean) nitrate less than 0.6 mg/L
- ❖ average total nitrogen (TN) less than 1.0 mg/L, and
- ❖ average total phosphorus (TP) are equal to or less than 0.1 mg/L AND

If nearby streams without wetlands meet DO criteria,

THEN determine as impaired due to natural condition

→ assess as category 4C in next assessment

→ initiate WQS reclassification to Class VII Swamp Water

→ get credit under consent decree

No Cattail Creek pH or DO water quality data, standard violations or non-violations were obtained at flows below 7Q10, therefore no data were removed.

The slopes of Cattail Creek and tributaries Collier and Massie Branches were determined as 0.34%, 0.19% and 0.42%, respectively (Table 5). These are lower than the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swamps and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts.

Cattail Creek and its tributaries exhibit low nutrient concentrations below national background levels in streams from undeveloped areas, which are not indicative of human impact.

Cattail Creek exhibits natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO.

There are no active permitted point source dischargers in the Cattail Creek watershed (K11R). However there is one Confined Animal Feeding Operation (CAFO) permit, Smithfield Carroll's Farm 93 (VPG100033). This facility land applies manure to fields, and is designed not to discharge from the fields, therefore it is not considered a point source. This facility is not expected to significantly impact DO or pH.

Urban areas compose approximately 3 percent of the land base, almost all of which occurs upstream of the impaired segment of the watershed. Agriculture makes up approximately 33 percent of the watershed. The watershed is predominately forested (56 percent), with 4 percent wetlands and open water. Land use was not considered to have significantly impacted the swampwater conditions of Cattail Creek and its tributaries. The percentages of forested and wetland landuses for tributaries Collier and Massie Branches are very similar to those on mainstem Cattail Creek.

Based on the above information, a change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is indicated for Cattail Creek and its tributaries located in waterbody identification codes (WBID, Virginia Hydrologic Unit) VAP-K11R and 03010204, a total of 31.79 rivermiles. If there is a 305(b)/303(d) assessment prior to the reclassification, Cattail Creek and these tributaries will be assessed as Category 4C, Impaired due to natural condition, no TMDL needed.

DEQ performed the assessment of the Cattail Creek tributaries low DO and low pH natural condition in lieu of a TMDL. Therefore neither a TMDL Technical Advisory Committee (TAC) meeting nor a public meeting was involved. Public participation will occur during the next water quality standards triennial review process.

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